



# Promoting fruit and vegetable consumption in rural China: Does off-farm work play a role?

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## Abstract

Although off-farm work plays a significant role in facilitating agricultural production and rural development and improving household welfare, little is known about whether off-farm work can promote fruit and vegetable consumption in rural areas of developing countries. This paper sheds new insights by estimating the impact of off-farm work on fruit and vegetable consumption, measured by purchasing frequencies and consumption expenditures. We employ a two-stage residual inclusion estimator to address the self-selection bias and analyze data collected from 558 rural households in China. The results show that household heads' off-farm work promotes rural households' fruit and vegetable consumption by significantly increasing purchasing frequencies and expenditures. Further analysis confirms that household heads' off-farm work participation, rather than all household members, plays a prominent role in promoting household fruit and vegetable consumption. We also find that farmers' behaviours of growing fruits and vegetables appear to substitute their purchasing behaviours.

**Keywords:** Off-farm work, Fruit consumption, Vegetable consumption, 2SRI model, Rural China

**JEL codes:** Q18, R23, E21

## 1 Introduction

Fruits and vegetables are essential parts of a healthy diet. Their inadequate daily consumption would result in micronutrient deficiencies and a wide range of diseases (e.g. heart diseases, cancer, and diabetes). It is reported that low fruit and vegetable consumption leads to around 1.7 million (2.8 per cent) deaths worldwide (WHO-FAO 2004). Specifically, insufficient fruit and vegetable consumption has caused appropriately 9 per cent of stroke deaths, 11 per cent of ischaemic heart disease deaths, and 14 per cent of gastrointestinal cancer deaths (WHO-FAO 2004).

A diet rich in fruit and vegetable would reduce the risk and the occurrence of physical diseases (Zhan *et al.* 2017; Tian *et al.* 2018; Farvid *et al.* 2019; Lee, Lim, and Kim 2019; Wolfenden *et al.* 2021). Increased fruit and vegetable intake reduces, for example, stroke risk (He, Nowson, and MacGregor 2006), coronary heart disease risk (Dauchet *et al.* 2006; Gan *et al.* 2015), cardiovascular diseases risk (Alissa and Ferns 2017; Zhan *et al.* 2017), inflammatory bowel disease risk (Milajerdi *et al.* 2020), breast cancer incidence (Farvid *et al.* 2019), and metabolic syndrome (Tian *et al.* 2018; Lee *et al.* 2019). Adequate intake

of fruits and vegetables also improves consumers' psychological well-being outcomes such as life satisfaction, happiness, depression, and distress (Bishwajit *et al.* 2017; Gehlich *et al.* 2019; Phillips *et al.* 2020).

The World Health Organization (WHO) recommends that fruit and vegetable consumption (excluding potatoes and other starchy tubers) should be no less than 146 kg/year/capita (equivalent to 400 g/day/capita) (WHO-FAO 2004; Choudhury *et al.* 2020). However, fruit and vegetable consumption is generally low worldwide, especially in rural regions of many developing countries (Dehghan, Akhtar-Danesh, and Merchant 2011; Kalmpourtzidou, Eilander, and Talsma 2020). In their meta-analysis for the vegetable intake of 162 countries, Kalmpourtzidou *et al.* (2020) found that vegetable intake in 88 per cent of the investigated countries is below the WHO recommended level. The significant benefits of fruit and vegetable consumption emphasize that it is vital to promote their consumption for shifting towards healthier and more sustainable diets. Ensuring sustainable consumption patterns of fruits and vegetables also contributes to the achievements of the Sustainable Development Goals of the United Nations regarding 'sustainable consumption and production' (Goal 12).

Agricultural production can affect the nutrition intake of rural households as sources of food and income (Gillespie, Harris, and Kadiyala 2012; Takeshima *et al.* 2020). Crops cultivated by the households can be translated into food for consumption, directly influencing the nutrition intake of rural people. Agriculture can also generate income through the marketed sales of food produced, facilitating rural households to purchase other food items such as fruits and vegetables for nutrition intake. However, relying solely on agriculture may be insufficient to improve dietary diversity and nutrition outcomes because, in reality, each household is cultivating limited land. Besides, income generated from agriculture is unstable due to, for example, market volatility and seasonality and uncertainties of weather conditions. As land is usually scarce for many rural households, diversifying household income is a more realistic strategy to diversify nutrition intake.

Low income is one of the most important barriers restricting people's adequate food consumption in general and fruit and vegetable intake in particular (Lallukka *et al.* 2010; Li *et al.* 2017; Kehoe *et al.* 2019; Choudhury *et al.* 2020; Kasprzak *et al.* 2020). Hall *et al.* (2009) investigated fruit and vegetable consumption of 196,737 adults from fifty-two low- and middle-income countries and found that around 77.6 per cent of men and 78.4 per cent of women have consumed fruits and vegetables below the recommended minimum level. Restrepo, Rabbitt, and Gregory (2021) reported that loss of income due to coronavirus-induced unemployment reduces household food expenditure in the United States. Lower income reduces consumers' purchasing power and their consumption diversity (Chai, Rohde, and Silber 2015). From sustainable development perspectives, there is a need to identify appropriate practical strategies that help increase incomes to boost fruit and vegetable intake.

Off-farm work is such a strategy. The importance of off-farm work in improving agricultural production, increasing rural incomes, and facilitating rural development has been well documented (e.g. Mathenge, Smale, and Tschirley 2015; Van den Broeck and Maertens 2017; Ma, Renwick, and Grafton 2018; Anang, Nkrumah-Ennin, and Nyaaba 2020; Zhou *et al.* 2020; Duong, Thanh, and Ancev 2021; Janvry and Sadoulet 2001; Zheng *et al.* 2021). There exist two strands of literature regarding the nexus between off-farm work and food consumption and security. The first strand of literature focuses on the impact of off-farm work/income on food expenditure (Chang and Mishra 2008; Chang and Yen 2010; Mishra, Mottaleb, and Mohanty 2015; Zereyesus *et al.* 2017; Liu, Renwick, and Fu 2019). Using a nationwide farm household survey in the United States, Chang and Mishra (2008) showed that the operator's off-farm work participation increases food expenditure, while the spouse's off-farm work participation decreases food expenditure. The study for Ghana

by Zereyesus *et al.* (2017) reveals that participation in off-farm work significantly increases the future expected food consumption, thereby alleviating households' vulnerability to food poverty. Liu *et al.* (2019) found an increase in off-farm income increases per capita food expenditure in rural China.

The second focuses on the impact of off-farm work on food security and nutrition (e.g. Babatunde *et al.* 2010; Owusu, Abdulai, and Abdul-Rahman 2011; Tsiboe, Zereyesus, and Osei 2016; Zereyesus *et al.* 2017; Kuwornu *et al.* 2018; Dzanku 2019; Pritchard, Rammohan, and Vicol 2019; Rahman and Mishra 2020; Schmidt, Mueller, and Rosenbach 2020). For example, Babatunde and Qaim (2010) revealed that off-farm income positively impacts food security and nutrition in Nigeria. By estimating data collected from six African countries (Ghana, Kenya, Malawi, Mozambique, Tanzania, and Zambia), Dzanku (2019) found that off-farm income has a positive and significant impact on food security, and such impacts on female-headed and poor region households are larger than it has on male-headed and rich region households in most countries. The study for rural Vietnam by Duong *et al.* (2021) reveals that off-farm employment ensures food security and contributes to poverty alleviation.

Despite the existence of numerous studies on off-farm work effects, there is still a lack of research exploring whether off-farm work can help promote fruit and vegetable consumption. Therefore, the present study contributes to the literature by furthering our understanding of potential strategies for promoting fruit and vegetable consumption, focusing on off-farm work. We consider two important consumption dimensions, including fruit and vegetable purchasing frequencies and consumption expenditures. The off-farm work variable is potentially endogenous because of its non-random nature (Owusu *et al.* 2011; Duong *et al.* 2021). Therefore, we employ an innovative two-stage residual inclusion (2SRI) approach to address the endogeneity issue of off-farm work. The data analyzed in this study are collected from rural households in the Shandong, Henan, and Anhui provinces of China. As a further contribution, we estimate how the off-farm income share and the off-farm worker share in a household affect fruit and vegetable consumption. As an additional understanding, we also provide evidence to show whether farmers' behaviours of growing fruits and vegetables substitute or complement their purchasing behaviours.

China is an interesting example. Due to the increased production of processed food, rapid urbanization, and changing lifestyles, people consume more foods with high energy, free sugars, salt but fewer fruits and vegetables. A survey showed that, in 2018, the fruits and vegetables consumed by rural households were, respectively, 36.3 and 85.6 kg/capita (121.9 kg/capita in total) (NBS 2020), which are lower than the WHO recommended level (146 kg/year/capita). WHO (2020) reports that people in China consume excessive amounts of cooking oil and more than double the recommended daily salt intake. An unhealthy diet leads to a rising prevalence of obesity and overweight and other body diseases such as cancers, diabetes, and cardiovascular diseases. China is now facing a high prevalence of diet-related non-communicable diseases (e.g. hypertension, stroke, and coronary heart disease) and micronutrient deficiency among adults and children, increasing the burden of healthcare costs (Yang *et al.* 2008; Wong *et al.* 2013; Chen *et al.* 2020; Huang *et al.* 2020). Given the importance of consuming more fruits and vegetables in a healthy diet, it is significant to promote their consumption in China. This study's findings would provide significant evidence that helps design programs and strategies for promoting fruit and vegetable consumption in China and other countries to improve individual and public health.

The rest of this paper is structured as follows. Section 2 introduces the estimation strategy, followed by Section 3, which introduces data and descriptive statistics. We present and discuss the empirical results in Section 4. The final section concludes and proposes implications.

## 2 Estimation strategy

### 2.1 Model selection

Rural farmers themselves decide whether or not to participate in off-farm work. Their participation decisions are affected by both observed factors (e.g. age, education, farm size, and household size) and unobserved factors (e.g. motivations to work and innate abilities) (Owusu *et al.* 2011; Kuwornu *et al.* 2018; Ma, Abdulai, and Ma 2018; Anang *et al.* 2020; Zhou *et al.* 2020). The fact indicates that off-farm work is an endogenous variable in the models estimating off-farm work impacts on fruit and vegetable consumption. Failing to address such an endogeneity issue would cause biased estimates.

The existing literature has applied different approaches to address the endogeneity issue of the treatment variable (off-farm work in this study). These include the propensity score matching (PSM) model (Owusu *et al.* 2011; Khachatryan, Baghdasaryan, and Hartarska 2019), difference-in-difference (DID) model (Azam and Saing 2017), PSM-DID model (Liu, Tan, and Zhang 2021), two-stage predictor substitution (2SPS) approach (Ma *et al.* 2021), and the 2SRI approach (Kumar *et al.* 2020; Zhu, Ma, and Leng 2020). The PSM model cannot identify the impacts of control variables on outcome variables due to its non-parametric nature, and it cannot consider the selection bias arising from unobserved characteristics. Both DID model and PSM-DID model require panel data for estimations, so they are not applicable as this study uses cross-sectional data. In comparison, two parametric methods, including the 2SPS approach and the 2SRI approach, can overcome the PSM approach's drawbacks and estimate cross-sectional data.

As argued by Terza, Basu, and Rathouz (2008) and Ying, Xu, and Murphy (2019), the 2SRI can provide consistent estimates of structural parameters and average partial/marginal effects while the 2SPS may be inconsistent. Thus, the estimation of the 2SRI model is usually more reliable than that of the 2SPS model. Several studies have applied the 2SRI model in their estimations (Kumar *et al.* 2020; Ma and Zhu 2020; Tesfaye and Tirivayi 2020; Zhu *et al.* 2020). For example, by applying the 2SRI approach, Kumar *et al.* (2020) estimated the impact of food safety measure adoption on milk yield and profitability of smallholder dairy farms in India, while Ma and Zhu (2020) examined the impact of the existence of agricultural cooperatives in rural villages on cropland abandonment in China. In this study, we also employ the 2SRI model to estimate the impact of off-farm work on fruit and vegetable consumption.

### 2.2 2SRI model

The 2SRI model estimation involves two stages. In the first stage, it estimates farmers' off-farm work participation equation. This study focuses on off-farm wage work because we do not identify any household heads having self-employed off-farm work in our sample. Following previous studies (Fernandez-Cornejo *et al.* 2007; Owusu *et al.* 2011; Ma *et al.* 2018), we assume that farmers compare the anticipated off-farm wage ( $W^O$ ) with the reservation wage ( $W^R$ ) when making off-farm work participation decisions. Here, reservation wage refers to the minimum wage that a farmer requires to participate in the labour markets. Because farmers are assumed to be rational in decision-making, they may choose to participate in the off-farm work if the anticipated off-farm wage is higher than the reservation wage. Let  $OF^*$  be the difference between the anticipated off-farm wage and the reservation wage, that is  $OF^* = W^O - W^R$ , farmers' decisions to participate in off-farm work can be modelled in a latent variable function as follows:

$$OF^* = \alpha_i X_i + \beta_i IV_i + \varepsilon_i, \quad OF_i = \begin{cases} 1, & \text{if } OF^* > 0 \\ 0, & \text{otherwise} \end{cases} \quad (1)$$

where  $OF^*$  represents the probabilities of off-farm work participation. It is identified by an observed variable  $OF_i$ , indicating whether a respondent  $i$  participated in any off-farm work ( $OF_i = 1$  for off-farm work participants and  $OF_i = 0$  for non-participants);  $X_i$  is a vector of variables that are expected to affect a respondent  $i$ 's decision to participate in off-farm work;  $IV_i$  is a vector of the instrumental variables used for model identification; and  $\varepsilon_i$  is an error term. Equation (1) can be estimated by a dichotomous model (Logit model in this study).

We select two variables to serve as instrument variables (IV) in Equation (1). The first (IV1) is a dichotomous variable measuring whether households' friends can offer help when finding off-farm work (1 = yes and 0 = no). Similarly, the second (IV2) identifies whether households can obtain assistance from neighbours on the off-farm job search (1 = yes and 0 = no). The choice of the two instruments is inspired by the significant role of social networks in labour allocation and agricultural production decisions, which has been highlighted in the existing studies (Ma and Wang 2020; Tesfaye and Tirivayi 2020; Zhou *et al.* 2020; Cole and Chen 2021). The assistance from friends and neighbours is expected to affect household heads' off-farm work participation, but it does not directly affect households' fruit and vegetable consumption. We have applied the Hansen  $J$ -tests to examine the issues of overidentification restrictions, and the results confirm the validity and effectiveness of the selected IVs.

In the second stage, the 2SRI approach estimates the impacts of off-farm work on fruit and vegetable consumption, captured by purchasing frequency and consumption expenditure. The models can be specified as follows:

$$PF_i = \gamma_i OF_i + \delta_i X_i + \eta_i Residual_i + \mu_i \quad (2a)$$

$$E_i^* = \vartheta_i OF_i + \omega_i X_i + \theta_i Residual_i + \psi_i, \quad E_i = \max(0, E_i^*) \quad (2b)$$

where  $PF_i$  refers to fruit purchasing frequency or vegetable purchasing frequency;  $E_i^*$  is a latent variable representing fruit expenditure or vegetable expenditure, captured by the observed value of  $E_i$ . In the present study, we define expenditure ( $E_i^*$ ) as a censored variable because some households in our sample did not purchase fruits or vegetables.  $OF_i$  refers to off-farm work participation status;  $X_i$  is defined earlier;  $Residual_i$  refers to a residual term predicted after estimating the Equation (1), and it is included in Equations (2a) and (2b) to address the endogeneity issue of the off-farm work variable;  $\gamma_i$ ,  $\delta_i$ ,  $\eta_i$ ,  $\vartheta_i$ ,  $\omega_i$ , and  $\theta_i$  are parameters to be estimated;  $\mu_i$  and  $\psi_i$  are two error terms.

The dependent variable  $PF_i$  in Equation (2a) is a count variable, and therefore, we employ a Poisson regression model to estimate it. Because the coefficient estimations of the Poisson regression cannot be explained as magnitudes, we follow previous studies (Erdogdu 2013; Ma and Wang 2020; Zhang *et al.* 2020) and calculate the incidence rate ratios (IRRs) of the independent variables to enhance our explanation and understanding. In particular, the IRR is calculated by exponentiating the count model regression coefficients, that is  $IRR = \exp(\text{coefficient})$ . For example, the IRR of the off-farm work variable in Equation (2a) is calculated as  $e^{\gamma_i}$ . The IRR estimates indicate the multiplicative effect of an independent variable on the dependent variable, telling us that the dependent variable is 'IRR' times its original value when one unit is added to an independent variable. Alternatively, one can say the incidence rate of the dependent variable increases by  $(IRR - 1) \times 100/100$  if  $IRR > 1$  or decreases by  $(1 - IRR) \times 100/100$  if  $0 < IRR < 1$  when one unit is added to an independent variable. Moreover, the expenditure variable  $E_i$  in Equation (2b) is censoring from zero as not all households purchase fruits or vegetables from the markets. Therefore, the Tobit model is employed to estimate Equation (2b).

### 3 Data and descriptive statistics

#### 3.1 Study context

Data collection was organized in the Shandong, Henan, and Anhui provinces of China between June and July 2019. Shandong is a coastal province of China and is part of the East China region. The province has a land area of 157,100 km<sup>2</sup>. Shandong is the second-most populous province of China, after Guangdong, with a population of 100.7 million by 2019 (NBS 2020). Shandong has a temperate climate, lying in the transition between the humid subtropical and humid continental zones with four distinct seasons. Annual precipitation is between 550 and 950 mm. Henan is located in the central part of China, which is a land-locked province of the country. The province has a land area of 167,000 km<sup>2</sup>. At the end of 2019, Henan has a population size of 96.4 million (NBS 2020). Henan has a diverse landscape with mountains in the west and floodplains in the east. The province has a temperate climate that is humid, subtropical to the south of the Yellow River, and bordering on humid continental to the north. Anhui province is part of the Central China region. The province has a land area of 140,100 km<sup>2</sup> and a population size of 63.66 million by 2019 (NBS 2020). Anhui is quite diverse topographically. The north of the province is part of the North China Plain, while the north-central areas are part of the Huai River watershed. As with topography, the province differs in climate from north to south. The north is more temperate and has more clear-cut seasons.

Shandong, Henan, and Anhui provinces differ significantly in terms of economic conditions, disposal incomes, and consumption levels. In 2019, the per capita GDPs were 70,129 Yuan/capita in Shandong, 55,825 Yuan/capita in Henan, and 58,072 Yuan/capita in Anhui (NBS 2020). The per capita disposable incomes were 31,597 Yuan in Shandong, 23,903 Yuan in Henan, and 26,415 Yuan in Anhui in 2019. Among the disposable income, the wage income (mainly from off-farm work) contributed to 57 per cent of disposable income in Shandong, 50 per cent in Henan, and 53 per cent in Anhui (CSY 2020). The net operating revenue (mainly from farm work) contributed to 21–23 per cent of disposable income in these three provinces. The consumption expenditures of urban and rural residents in Shandong were 26,731 and 12,309 Yuan/capita in Shandong, 21,972 and 11,546 Yuan/capita in Henan, and 23,782 and 14,546 Yuan/capita in Anhui (NBS 2020). In 2019, rural people employed in farm and off-farm sectors in Shandong, Henan, and Anhui provinces were 28.91, 44.17, and 29.69 million, respectively.

#### 3.2 Sampling method

A multi-stage sampling technique was utilized to select rural households. The survey was conducted in Shandong, Henan, and Anhui provinces in China. After purposely selecting the three provinces, two cities from each province were randomly selected in the second stage. These include Linyi and Zaozhuang in Shandong, Xinyang and Zhumadian in Henan, and Suzhou and Huaibei in Anhui. Third, around two to three towns in each selected city were randomly chosen. Fourth, appropriately two to three villages were selected from each selected town. Finally, around ten to thirty farm households were randomly selected in each selected village. This sampling procedure helped collect a total sample of 558 rural households. Among them, 164 household heads participated in off-farm work in 2018, and the rest 394 did not.

Well-trained enumerators carried out a face-to-face interview with the respondents. The enumerators are all postgraduate students hired from an agricultural-based university in China. The questionnaire used for data collection covered information on fruit and vegetable consumption frequencies and expenditures, individual and household-level characteristics, socioeconomic characteristics, and various institutional and contextual variables. The survey also required respondents to provide comprehensive information on the off-farm work participation status of household heads and other household members, as well as total



**Table 1.** Variable definitions and summary statistics.

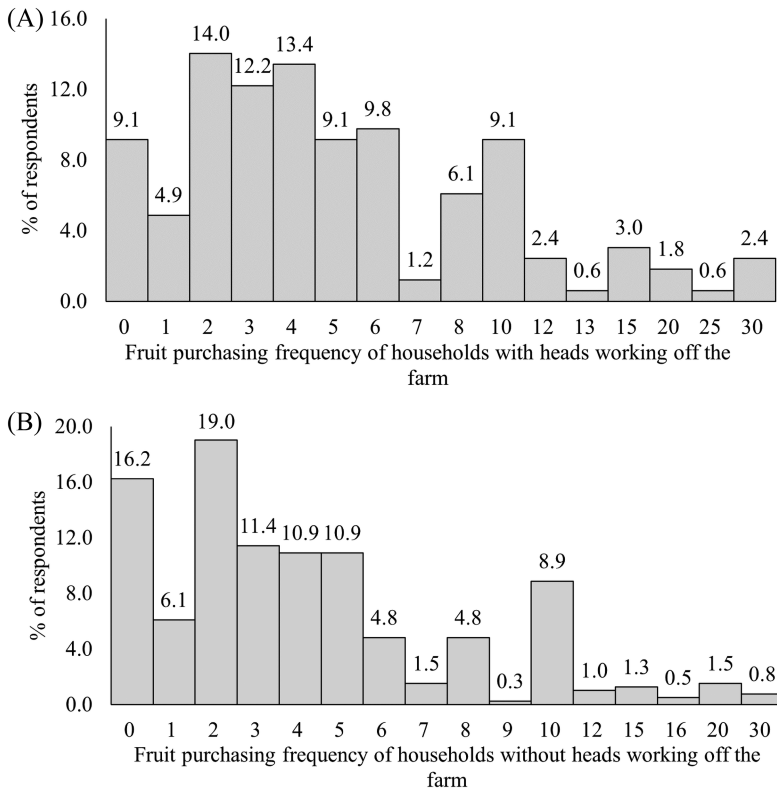
Variables	Definition	Mean (SD)
<i>Dependent variables</i>		
Fruit frequency	Fruit purchasing frequency (times/month)	4.81 (4.97)
Vegetable frequency	Vegetable purchasing frequency (times/month)	7.07 (8.23)
Fruit expenditure	Expenditure on fruits (100 Yuan/month) <sup>a</sup>	0.89 (1.37)
Vegetable expenditure	Expenditure on vegetables (100 Yuan/month)	1.13 (1.62)
<i>Key explanatory variables</i>		
Off-farm work	1 if household head participated in off-farm work in 2018, 0 otherwise	0.29 (0.46)
Off-farm income ratio	Ratio of household off-farm income to total household income	0.50 (0.37)
Off-farm worker ratio	Ratio of the number of off-farm workers to household size	0.29 (0.23)
Off-farm work intensity	Total time used for off-farm work by household heads (0–12 months)	2.02 (3.68)
<i>Control variables</i>		
Age	Age of household head (years)	56.50 (11.22)
Gender	1 if household head is male, 0 otherwise	0.60 (0.49)
Education	Educational level of household head (years)	4.73 (3.84)
Household size	Number of household members (persons)	4.70 (2.45)
Farm size	Total farm size for agricultural production (mu) <sup>b</sup>	9.07 (11.31)
Elder member ratio	Ratio of elder members (>65 years old) to household size	0.22 (0.33)
Child member ratio	Ratio of child members (<15 years old) to household size	0.16 (0.17)
Asset ownership	1 if household owns a farm machine, 0 otherwise	0.81 (0.40)
Shandong	1 if household resides in Shandong province, 0 otherwise	0.48 (0.50)
Henan	1 if household resides in Henan province, 0 otherwise	0.26 (0.44)
Anhui	1 if household resides in Anhui province, 0 otherwise	0.26 (0.44)
IV1	1 if household can obtain help from friends when finding an off-farm job, 0 otherwise	0.11 (0.31)
IV2	1 if household can obtain help from neighbours when finding an off-farm job, 0 otherwise	0.03 (0.16)
Observations		558

*Note:* SD refers to the standard deviation.  
<sup>a</sup> Yuan is Chinese currency (1 USD = 6.90 Yuan in 2019).  
<sup>b</sup> 1 mu = 1/15 hectare.

off-farm income. This helps enrich our understanding of the relationship between off-farm work and fruit and vegetable consumption from different dimensions. Rural households usually consume different types of fruits and vegetables without paying attention to how many grams they have eaten each day. Therefore, we focus on their purchasing frequency and total consumption expenditure rather than consumption quantity and types to simplify our analysis.

3.3 Descriptive statistics

Table 1 presents the summary statistics of selected variables. It shows that, on average, rural households in our samples purchase 4.8 times fruits and 7.1 times vegetables each month.



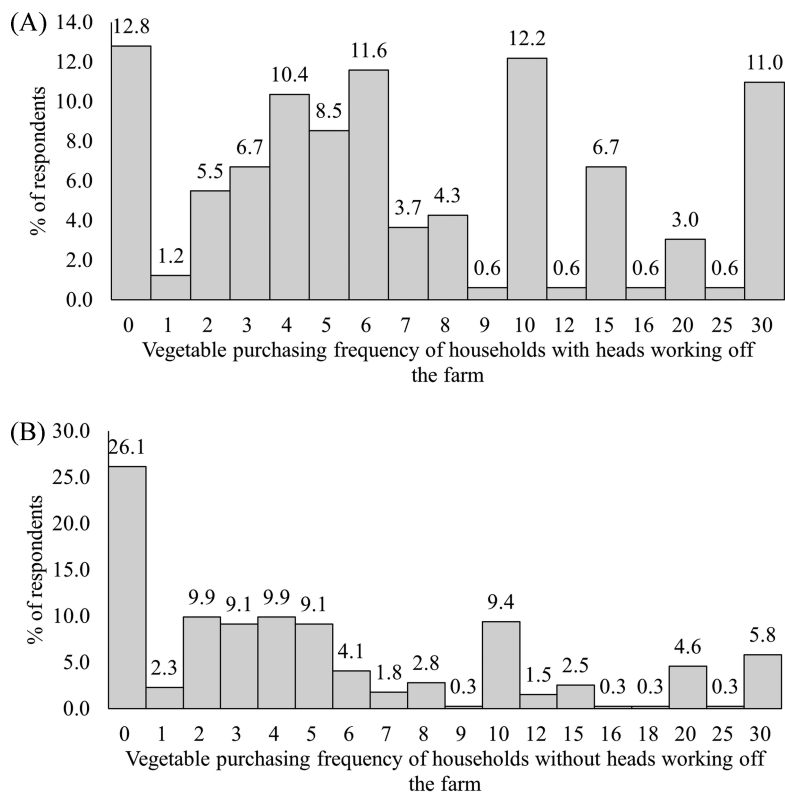
**Figure 1.** Distributions of fruit purchasing frequencies of households with and without heads working off the farm.

In our sample, the average expenditures on fruits and vegetables are 89 Yuan/month (1 Yuan = 0.15 USD) and 113 Yuan/month, respectively. Around 29 per cent of household heads had worked off the farm in 2018. Among control variables, we show that the average age of household heads was 56.5 years, and 60 per cent of them were male. There are approximately five members within sampled households. The number of elder members and child members accounts for 22 per cent and 16 per cent of total household size, respectively.

Figs 1 and 2 depict the histogram distributions of fruit and vegetable purchasing frequencies, respectively. They show notable differences in fruit and vegetable purchasing frequencies between households with heads working off the farm ( $n = 164$ ) and households without heads working off the farm ( $n = 394$ ). Specifically, around 59 per cent of households with heads working off the farm purchased fruits between 2 and 6 times per month (Fig. 1a), while only 51 per cent of their counterparts without heads working off the farm do it in that way (Fig. 1b). Fig. 2 shows that around 6.7 per cent of households with heads working off the farm purchased vegetables only 1 or 2 times per month, while this value is almost doubled, which is 12.2 per cent, for households without heads working off the farm. In general, the information presented in Figs 1 and 2 suggests that household heads' off-farm work participation may have impacts on fruit and vegetable purchasing frequencies.

Table 2 reports the mean differences of the dependent variables and control variables between off-farm work participants and non-participants. In general, we show that relative to non-participants, off-farm work participants have relatively higher frequencies of purchasing fruits and vegetables. They also spend more on both fruits and vegetables. The findings





**Figure 2.** Distributions of vegetable purchasing frequencies of households with and without heads working off the farm.

tend to indicate that off-farm work participation increases fruit and vegetable consumption in rural China. However, the mean comparison results are not rigorous because they do not consider other factors that may affect farmers’ decisions to participate in off-farm work and their fruit and vegetable consumption decisions. Table 2 clearly shows that off-farm work participants and non-participants are systematically different in age, gender, and education of household heads, and elder member ratio. These observable differences highlight the necessity of employing a rigorous econometric approach such as the 2SRI model to analyze the impact of off-farm work on fruit and vegetable consumption.

#### 4 Empirical results

This section discusses the empirical results estimated based on the 2SRI approach. Specifically, Section 4.1 presents and discusses the results estimated for the first stage of the 2SRI approach, which reports the factors affecting off-farm work participation. Sections 4.2 and 4.3 discuss the results estimated for the second-stage of the 2SRI approach, focusing on the impacts of off-farm work and other control variables on fruit and vegetable purchasing frequencies and consumption expenditure, respectively. Finally, we present and discuss some additional analysis results to improve our understanding of the nexus between off-farm work and fruit and vegetable consumption.

**Table 2.** Mean differences of the selected variables by off-farm participation status of household heads.

Variables	Participants	Non-participants	Mean differences
Fruit frequency	5.84 (5.82)	4.39 (4.51)	1.46**
Vegetable frequency	8.96 (8.86)	6.28 (7.83)	2.68**
Fruit expenditure	1.15 (1.79)	0.79 (1.14)	0.36**
Vegetable expenditure	1.55 (1.87)	0.96 (1.48)	0.58**
Age	50.62 (10.88)	58.95 (10.43)	−8.34**
Gender	0.66 (0.48)	0.58 (0.49)	0.08*
Education	6.25 (3.47)	4.10 (3.81)	2.15**
Household size	4.65 (2.18)	4.73 (2.56)	−0.08
Farm size	8.96 (8.63)	9.11 (12.26)	−0.15
Elder member ratio	0.11 (0.22)	0.27 (0.36)	−0.16**
Child member ratio	0.16 (0.17)	0.16 (0.17)	0.00
Asset ownership	0.78 (0.42)	0.82 (0.39)	−0.04
Shandong	0.61 (0.49)	0.42 (0.49)	0.19**
Henan	0.17 (0.38)	0.29 (0.46)	−0.12**
Anhui	0.22 (0.42)	0.28 (0.45)	−0.06
IV1	0.22 (0.42)	0.06 (0.23)	0.16**
IV2	0.06 (0.24)	0.01 (0.11)	0.05**
Observations	164	394	

Note: \* < 0.10 and \*\* < 0.01. Standard deviation is presented in parentheses.

4.1 Factors affecting off-farm work participation of household heads

The results that report the factors determining farmers’ decisions to work off the farm are presented in the second column of Table 3. As the coefficients of the variables are not straightforward in interpretation, we calculate and present the marginal effects in the last column of Table 3 to facilitate our explanation. In general, our estimates show that household heads’ decisions to work off the farm are positively affected by their gender and education but negatively influenced by their age and elder and child member ratios. For example, the significant marginal effect of the gender variable suggests that male farmers are 8.7 percentage points more likely to participate in off-farm work relative to their female counterparts. In developing countries like China, men are more likely to migrate to urban regions to seek better-salary opportunities in off-farm sectors, while women are usually left at home to undertake household activities.

The age variable has a negative and statistically significant marginal effect. The finding suggests that farmers are 1.1 percentage points less likely to work off the farm if their age increases one year. Compared with younger farmers, older ones are usually less competitive

**Table 3.** First stage estimates of the 2SRI model: Factors affecting off-farm work participation of household heads.

Variables	Coefficients	Marginal effects
Age	−0.072 (0.013)**	−0.011**
Gender	0.558 (0.252)*	0.087*
Education	0.081 (0.032)*	0.013*
Household size	0.046 (0.062)	0.007
Farm size	−0.007 (0.011)	−0.001
Elder member ratio	−1.015 (0.513)*	−0.158*
Child member ratio	−2.669 (0.818)**	−0.415**
Asset ownership	−0.409 (0.270)	−0.064
Shandong	0.760 (0.277)**	0.118**
Henan	−0.141 (0.340)	−0.022
IV1	1.230 (0.321)**	0.191**
IV2	1.885 (0.629)**	0.293**
Constant	2.513 (0.768)**	
Observations	558	

Note: \* < 0.05 and \*\* < 0.01. The reference province is Anhui. Standard errors are presented in parentheses.

in the off-farm work markets due to unfavourable health conditions and working skills. For this reason, they are less motivated to work off the farm. Our results echo the findings of Cole and Chen (2021), who also reported a negative relationship between age and off-farm employment in New England. The positive and statistically significant marginal effects of the variables representing elder member ratio and child member ratio suggest that one unit increase in elder member ratio and child member ratio would decrease the probabilities of off-farm work participation by 15.8 and 41.5 percentage points, respectively. The findings are expected. Higher ratios of elder and child members mean a potential shortage of available labour force in a household, limiting the household heads' ability and motivation to leave home for off-farm works. Ahmed and Melesse (2018) provided similar results that members living in households without abundant labour are less likely to engage themselves in off-farm activities.

4.2 Factors affecting fruit and vegetable purchasing frequencies

Table 4 presents the results for the impacts of off-farm work and other control variables on fruit and vegetable purchasing frequencies. Poisson regression model estimates the results using Equation (2a). As discussed earlier, we calculate and discuss the IRRs results (last two columns of Table 4) to facilitate our discussion because the coefficient estimates of the Poisson regression model (columns 2 and 3) do not reflect the magnitudes. The residual of the off-farm work variable, which is predicted from the first-stage estimation, is included as an additional regressor to account for the endogeneity issue. The residual term's coefficient

**Table 4.** Second stage estimates of the 2SRI model: Factors affecting fruit and vegetable purchasing frequencies.

Variables	Poisson model		Poisson model	
	Fruit purchasing frequency (coefficients)	Vegetable purchasing frequency (coefficients)	Fruit purchasing frequency (IRRs)	Vegetable purchasing frequency (IRRs)
Off-farm work	0.358 (0.141)**	0.272 (0.118)**	1.430**	1.312**
Age	−0.009 (0.003)***	−0.019 (0.003)***	0.991***	0.981***
Gender	−0.114 (0.046)**	0.361 (0.039)***	0.892**	1.434***
Education	0.014 (0.006)**	−0.014 (0.005)**	1.014**	0.986***
Household size	0.056 (0.010)***	0.051 (0.009)***	1.057***	1.052***
Farm size	0.002 (0.002)	−0.004 (0.002)**	1.002	0.996**
Elder member ratio	−0.381 (0.097)***	−0.085 (0.074)	0.683***	0.919
Child member ratio	0.688 (0.149)***	0.309 (0.124)**	1.989***	1.362**
Asset ownership	0.053 (0.051)	−0.035 (0.040)	1.054	0.965
Shandong	0.290 (0.053)***	0.393 (0.043)***	1.337***	1.482***
Henan	−0.127 (0.063)**	−0.184 (0.054)***	0.881**	0.832***
Residual (off-farm work)	−0.144 (0.062)**	−0.094 (0.051)*	0.866**	0.911*
Constant	1.451 (0.199)***	2.378 (0.166)***	4.269***	10.782***
Observations	558	558	558	558

Note: \* < 0.10, \*\* < 0.05, and \*\*\* < 0.01. The reference province is Anhui. Standard errors are presented in parentheses.

in column 2 of Table 4 is negative and statistically significant, suggesting the presence of endogeneity issues stemming from unobserved heterogeneities (Terza et al. 2008; Ying et al. 2019; Zhu et al. 2020).

The results show that off-farm work significantly increases fruit purchasing frequency by a factor of 1.430 and vegetable purchasing frequency by a factor of 1.312. The findings suggest that off-farm work participants purchase fruits and vegetables each month 1.430 and 1.312 times more than their non-participant counterparts, given the other variables are held constant in the model. Participation in off-farm work allows household heads to send remittance to their families for regularly purchasing fresh fruits and vegetables.

We show that rural households' fruit and vegetable purchasing frequencies are also affected by other factors. For example, the coefficients of the age variable are negative and statistically significant. The IRR estimates suggest that if the age of a household head were to increase by one year, the rate ratios for purchasing fruits and vegetables would be expected to decrease by 0.9 per cent [i.e. (1−0.991) × 100/100] and 1.9 per cent [i.e. (1−0.981) × 100/100], respectively, while holding all other variables in the model constant. By investigating nationally representative data of 170,847 adults from China, Li et al. (2017) also found that old age is associated with low fruit and vegetable consumption. The household

**Table 5.** Second stage estimates of the 2SRI model: Factors affecting expenditures on fruits and vegetables.

Variables	Tobit model	
	Fruit consumption expenditure (coefficients)	Vegetable consumption expenditure (coefficients)
Off-farm work	0.955 (0.454)**	1.041 (0.600)*
Age	−0.021 (0.010)**	−0.014 (0.013)
Gender	−0.087 (0.143)	0.065 (0.191)
Education	−0.011 (0.019)	−0.004 (0.025)
Household size	0.102 (0.034)***	0.066 (0.045)
Farm size	0.001 (0.006)	0.007 (0.008)
Elder member ratio	0.070 (0.264)	0.008 (0.348)
Child member ratio	1.318 (0.491)***	1.481 (0.651)**
Asset ownership	0.064 (0.158)	−0.447 (0.206)**
Shandong	0.295 (0.159)*	0.261 (0.210)
Henan	−0.185 (0.178)	−0.320 (0.237)
Residual (off-farm work)	−0.389 (0.192)**	−0.249 (0.254)
Constant	0.873 (0.638)	1.018 (0.845)
Observations	558	558

*Note:* \* < 0.10, \*\* < 0.05, and \*\*\* < 0.01. The reference province is Anhui. Standard errors are presented in parentheses. Fruit consumption expenditure and vegetable consumption expenditure are measured at 100 Yuan/month.

size variable appears to have a positive and significant impact on fruit and vegetable purchasing frequencies. The IRR estimates show that an additional member increase in a household would increase the incidence rates of purchasing fruits by 5.7 per cent and purchasing vegetables by 5.2 per cent. The coefficient of elder member ratio variable is negative and statistically significant in the second column of Table 4. The corresponding IRR estimate suggests that one unit increase in the elder member ratio would result in a 31.7 per cent reduction in fruit purchasing incidence rate, holding other variables in the model constant. This is possibly because older people may prefer consuming their self-produced agricultural products rather than purchasing them from the markets.

4.3 Factors affecting fruit and vegetable consumption expenditures

Table 5 demonstrates the results for the impacts of off-farm work and control variables on expenditures on fruits and vegetables, which are estimated by the Tobit model and Equation (2b). The significant coefficient of the off-farm work residual term in column 2 of Table 5 again confirms the existence of the endogeneity issue and the necessity of employing the 2SRI model to address it.

The results show that the off-farm work variable’s coefficients are positive and statistically significant, suggesting that monthly household expenditure on fruits and vegetables would

increase if household heads participate in off-farm work. In particular, our estimates suggest that, on average, households with heads participating in off-farm work spend 96 Yuan more on fruits and 104 Yuan more on vegetables than households whose heads did not work off the farm. Off-farm work participation of household heads increases household income, allowing the households to purchase more fruits and vegetables to enrich diets. The findings are largely supported by the income-increasing effects of off-farm work, showing a positive relationship between off-farm work/income and household consumption (Mishra *et al.* 2015; Al-Amin and Hossain 2019; Hossain and Al-Amin 2019).

Other factors also affect fruit and vegetable consumption of rural households in China. For example, the variable representing the child member ratio has positive and statistically significant coefficients in Table 5. The findings suggest that households with more children younger than 15 years old spend more on fruits and vegetables, which are largely consistent with the results in the existing literature (Blanchette and Brug 2005; Qian *et al.* 2016). Fruit and vegetable eating habits initiated in childhood would persist into adulthood, and starting the habit from childhood could provide life-long benefits for health (Blanchette and Brug 2005; Hirvonen and Hoddinott 2017). A poor fruit and vegetable diet in childhood may sow the seeds of serious health problems associated with older adults, while early intervention by consuming more fruits and vegetables can help reap the maximum health benefits. Ownership of assets (farm machine in this study) has a negative and significant impact on vegetable consumption expenditure. As essential production equipment, farm machinery improves farmers' efficiency when undertaking farm activities (e.g. land preparation and pesticide application), motivating farmers' intention to plant vegetables themselves but reducing farmers' interests to purchase vegetables from the markets. This fact leads to reduced expenditure on vegetables.

## 4.4 Further estimates

### 4.4.1 Impacts of off-farm work intensity

Our analyses in Sections 4.2 and 4.3 have focused on household heads' binary decision of off-farm work participation. As an additional understanding, we investigate how off-farm work intensity affects fruit and vegetable consumption, using the 2SRI approach. The off-farm working intensity refers to the total time (measured in months) allocated to off-farm work activities by household heads. For the sake of simplicity, we only present the results of the off-farm work intensity variable. The results [see Estimation (1) in Table A1 in Appendix A] show that off-farm work intensity affects fruit and vegetable purchasing frequencies positively and significantly. In comparison, off-farm work intensity is only significantly associated with a higher vegetable consumption expenditure.

### 4.4.2 Impacts of off-farm income ratio and off-farm worker ratio

Previous analyses have exclusively focused on household heads. To enrich our analyses, we have also estimated the impacts of the off-farm income ratio and off-farm worker ratio at the household level on fruit and vegetable consumption, using the 2SRI approach. In particular, the off-farm income ratio refers to the ratio of off-farm income to total household income. The off-farm worker ratio refers to the ratio of the number of off-farm work participants in a household to household size. These two variables capture the different dimensions of off-farm work participation within a household. For the sake of simplicity, in Table A1 in Appendix A, we only present the results of the key variables estimated from the second-stage estimations of the 2SRI model.

Our estimates [see Estimation (2) in Table A1] show that a higher off-farm income ratio in a household has a significantly positive relationship with vegetable purchasing frequency and fruit consumption expenditure. Its impacts on fruit purchasing frequency and vegetable consumption expenditure are also positive though not statistically significant.



Off-farm work of household members would generate additional income and contribute to increased household income, empowering households' ability to purchase fruits and vegetables. Besides, a higher off-farm worker ratio is only positively and significantly (at a 10 per cent level) associated with higher fruit consumption expenditure [see Estimation (3) in Table A1]. By comparing the results in Tables 4 and 5 with the results in Table A1, we can conclude that the off-farm work participation of household heads, rather than all household members, plays a prominent role in promoting household fruit and vegetable consumption. For optimal intra-household resource allocation, households may choose to allocate off-farm income generated by the heads to food consumption and the off-farm income generated by other members to other household activities such as building houses, purchasing durable goods, and business investment.

#### 4.4.3 The nexus between fruit and vegetable growing and household purchasing

Some surveyed farm households have grown fruits (e.g. peach, pear, watermelon, grape, and apricot) and vegetables (e.g. potato, tomato, bean, eggplant, chilli, and cucumber) by themselves either for commercial purposes or self-consumption. Thus, it is interesting to understand how (substitutively or complementarily) farmers' fruit and vegetable growing behaviours affect their purchasing behaviour. We have created two dummy variables, including fruit growing and vegetable growing, to identify the growing status. The fruit growing variable is given a value of one if a farm household produces any fruits and zero otherwise. Similarly, the vegetable growing variable is given a value of one if a farm household produces any vegetables and zero otherwise.

Afterwards, we estimate the impact of fruit and vegetable growing status on fruit and vegetable purchasing frequencies and expenditures. The results (Table A2 in Appendix A) show that farmers' fruit and vegetable growing behaviours affect their purchasing behaviours negatively, and the influences are almost all statistically significant (except for the impacts on fruit consumption expenditure). The findings suggest that farmers' fruit and vegetable growing behaviours and their purchasing behaviours are substitutes.

## 5 Conclusion

In essence, off-farm work helps diversify household income and relax capital constraints, enabling people to consume more food, including fruits and vegetables. However, to date, the empirical evidence on the association between off-farm work and fruit and vegetable consumption is rare. This study addressed this research gap by empirically analyzing household survey data collected from rural China. We employed the 2SRI model to address the endogeneity issue associated with off-farm work.

The empirical results showed that off-farm work participation of household heads significantly increases fruit and vegetable purchasing frequencies and consumption expenditures. We found that rural households' fruit and vegetable purchasing frequencies are also positively affected by household size and child member ratio but are negatively influenced by the age of household heads and elder member ratio. Consumption expenditure on fruits was found to be positively associated with household size and child member ratio, and that on vegetables was mainly determined by child member ratio and asset ownership. The additional analyses revealed that a higher off-farm income ratio is positively and significantly associated with an increased vegetable purchasing frequency and higher expenditure on fruits. A higher off-farm worker ratio is exclusively correlated with higher expenditure on fruits. Finally, we showed that farmers' behaviours of growing fruits and vegetables appear to substitute their purchasing behaviours.

Our findings highlight the importance of encouraging rural labourers, especially household heads, to participate in off-farm works in promoting household consumption of fruits and vegetables. By doing this, the government may consider further improving rural

labourers' accessibility to off-farm work information by virtue of modern information and communication technologies such as smartphones. The findings that older and female household heads are less likely to participate in off-farm work suggest that designing targeted supporting policies and training programs for these farmers is essential to ensure they obtain an off-farm job when there is a need. Education enhances off-farm work participation. The finding highlights the importance of improving literacy education in rural areas.

This study is subject to two limitations. First, it is a cross-section analysis based on data collected from 558 households in three provinces in China. Thus, it is not possible to capture the time-variant characteristics that may affect peoples' consumption behaviours. Second, we have only focused on purchasing frequencies and expenditures when capturing rural households' intake of fruits and vegetables. It might be interesting for future studies to look at how off-farm work impacts nutrition intake (e.g. protein, fat, and fibre) as a higher quantity of fruit and vegetable intake is not necessarily associated with a nutritious diet. Future studies may also expand our analysis by investigating how the majority Han Chinese people's and the ethnic minority people's off-farm work participation influences their fruit and vegetable consumption. Traditionally, these two groups of people have different dietary habit structures.

## Conflict of interest

There is no conflict of interest.

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## Data availability

The data that support the findings of this study are available from the corresponding author, Hongyun Zheng, upon reasonable request.

## References

- Ahmed M. H. and Melesse K. A. (2018) 'Impact of off-farm activities on technical efficiency: evidence from maize producers of eastern Ethiopia', *Agricultural and Food Economics*, 6 (1): 1–15.
- Al-Amin A. K. M. A. and Hossain M. J. (2019) 'Impact of non-farm income on welfare in rural Bangladesh: multilevel mixed-effects regression approach', *World Development Perspectives*, 13: 95–102.
- Alissa E. M. and Ferns G. A. (2017) 'Dietary fruits and vegetables and cardiovascular diseases risk', *Critical Reviews in Food Science and Nutrition*, 57: 1950–62.
- Anang B. T., Nkrumah-Ennin K. and Nyaaba J. A. (2020) 'Does off-farm work improve farm income? Empirical evidence from Tolon district in northern Ghana', *Advances in Agriculture*, 1–8. <https://doi.org/10.1155/2020/1406594>.
- Azam M. and Saing C. H. (2017) 'Assessing the Impact of district primary education program in India', *Review of Development Economics*, 21 (4): 1113–31.
- Babatunde R. O., Olagunju F. I., Fakayode S. B. and Adejobi A. O. (2010) 'Determinants of Participation in Off-farm Employment Among Small-holder Farming Households in Kwara State', Nigeria. Accessed January. [www.patnsukjournal.net/currentissue](http://www.patnsukjournal.net/currentissue)
- Babatunde R. O. and Qaim M. (2010) 'Impact of off-farm income on food security and nutrition in Nigeria', *Food Policy*, 35 (4): 303–11.
- Bishwajit G., O'Leary D. P., Ghosh S., Sanni Y., Shangfeng T. and Zhanchun F. (2017) 'Association between depression and fruit and vegetable consumption among adults in South Asia', *BMC Psychiatry [Electronic Resource]*, 17 (1): 1–9.

- Blanchette L. and Brug J. (2005) 'Determinants of fruit and vegetable consumption among 6–12-year-old children and effective interventions to increase consumption', *Journal of Human Nutrition and Dietetics*, 18 (6): 431–43.
- Chai A., Rohde N. and Silber J. (2015) 'Measuring the diversity of household spending patterns', *Journal of Economic Surveys*, 29 (3): 423–40.
- Chang H.-H. and Mishra A. (2008) 'Impact of off-farm labor supply on food expenditures of the farm household', *Food Policy*, 33 (6): 657–64.
- Chang H.-H. and Yen S. T. (2010) 'Off-farm employment and food expenditures at home and away from home', *European Review of Agricultural Economics*, 37 (4): 523–51.
- Chen H., Zhou Y., Sun L., Chen Y., Qu X., Chen H., Rajbhandari-Thapa J. and Xiao S. (2020) 'Non-communicable diseases are key to further narrow gender gap in life expectancy in Shanghai, China', *BMC Public Health [Electronic Resource]*, 20 (1): 1–9.
- Choudhury S., Shankar B., Aleksandrowicz L., Tak M., Green R., Harris F., Scheelbeek P. and Dangour A. (2020) 'What underlies inadequate and unequal fruit and vegetable consumption in India? An exploratory analysis', *Global Food Security*, 24: 100332.
- Cole A. and Chen X. (2021) 'Off-farm employment in aquaculture: a case study of New England's oyster growers', *Canadian Journal of Agricultural Economics*, December 2020, 1–14.
- CSY. (2020) *China Statistics Yearbook*. Beijing: China Statistics Press.
- Dauchet L., Amouyel P., Hercberg S. and Dallongeville J. (2006) 'Fruit and vegetable consumption and risk of coronary heart disease: a meta-analysis of cohort studies', *Journal of Nutrition*, 136 (10): 2588–93.
- Dehghan M., Akhtar-Danesh N. and Merchant A. T. (2011) 'Factors associated with fruit and vegetable consumption among adults', *Journal of Human Nutrition and Dietetics*, 24 (2): 128–34.
- Duong P. B., Thanh P. T. and Ancev T. (2021) 'Impacts of off-farm employment on welfare, food security and poverty: evidence from rural Vietnam', *International Journal of Social Welfare*, 30: 84–96.
- Dzanku F. M. (2019) 'Food security in rural sub-Saharan Africa: exploring the nexus between gender, geography and off-farm employment', *World Development*, 113: 26–43.
- Erdogdu E. (2013) 'A cross-country analysis of electricity market reforms: potential contribution of New Institutional Economics', *Energy Economics*, 39: 239–51.
- Farvid M. S., Chen W. Y., Rosner B. A., Tamimi R. M., Willett W. C. and Eliassen A. H. (2019). 'Fruit and vegetable consumption and breast cancer incidence: repeated measures over 30 years of follow-up', *International Journal of Cancer*, 144 (7): 1496–510.
- Fernandez-Cornejo J., Mishra A. K., Nehring R. F., Hendricks C., Southern M. and Gregory A. (2007) 'Off-farm income, technology adoption, and farm economic performance', In *Economic Research Report—Economic Research Service/USDA*, United States Department of Agriculture.
- Gan Y., Tong X., Li L., Cao S., Yin X., Gao C., Herath C., Li W., Jin Z., Chen Y. and Lu Z. (2015) 'Consumption of fruit and vegetable and risk of coronary heart disease: a meta-analysis of prospective cohort studies', *International Journal of Cardiology*, 183: 129–37.
- Gehlich K. H., Beller J., Lange-Asschenfeldt B., Köcher W., Meinke M. C. and Lademann J. (2019) 'Fruit and vegetable consumption is associated with improved mental and cognitive health in older adults from non-Western developing countries', *Public Health Nutrition*, 22 (4): 689–96.
- Gillespie S., Harris J. and Kadiyala S. (2012) 'The agriculture-nutrition disconnect in India what do we know?' *IFPRI Discussion Paper 1187*, June, pp. 1–56.
- Hall J. N., Moore S., Harper S. B. and Lynch J. W. (2009) 'Global variability in fruit and vegetable consumption', *American Journal of Preventive Medicine*, 36 (5): 402–9.
- He F. J., Nowson C. A. and MacGregor G. A. (2006). 'Fruit and vegetable consumption and stroke: meta-analysis of cohort studies', *Lancet*, 367 (9507): 320–6.
- Hirvonen K. and Hoddinott J. (2017) 'Agricultural production and children's diets: evidence from rural Ethiopia', *Agricultural Economics (United Kingdom)*, 48 (4): 469–80.
- Hossain M. J. and Al-Amin A. K. M. A. (2019) 'Non-farm income and consumption expenditures in rural Bangladesh: empirical evidence from multilevel regression modelling', *Journal of Quantitative Economics*, 17 (2): 377–96.
- Huang Q., Wang L., Jiang H., Wang H., Zhang B., Zhang J., Jia X. and Wang Z. (2020) 'Intra-individual double burden of malnutrition among adults in China: evidence from the China Health and Nutrition Survey 2015', *Nutrients*, 12 (9): 2811.

- Janvry A. D. E. and Sadoulet E. (2001) 'Income strategies among rural households in Mexico: the role of off-farm activities', *World Development*, 29 (3): 467–80.
- Kalmpourtzidou A., Eilander A. and Talsma E. F. (2020) 'Global vegetable intake and supply compared to recommendations: a systematic review', *Nutrients*, 12 (6): 22–9.
- Kasprzak C. M., Sauer H. A., Schoonover J. J., Lapp M. M. and Leone L. A. (2020) 'Barriers and facilitators to fruit and vegetable consumption among lower-income families: matching preferences with stakeholder resources', *Journal of Hunger and Environmental Nutrition*, 1–19. <https://doi.org/10.1080/19320248.2020.1802383>.
- Kehoe S. H., Dhurde V., Bhaise S., Kale R., Kumaran K., Gelli A., Rengalakshmi R., Lawrence W., Bloom I., Sahariah S. A., Potdar R. D. and Fall C. H. D. (2019) 'Barriers and facilitators to fruit and vegetable consumption among rural Indian women of reproductive age', *Food and Nutrition Bulletin*, 40 (1): 87–98.
- Khachatryan K., Baghdasaryan V. and Hartarska V. (2019) 'Is the model "loans-plus-savings" better for microfinance in Eastern Europe and Central Asia? A propensity score matching comparison', *Review of Development Economics*, 23 (3): 1309–30.
- Kumar A., Mishra A. K., Saroj S., Sonkar V. K., Thapa G. and Joshi P. K. (2020) 'Food safety measures and food security of smallholder dairy farmers: empirical evidence from Bihar, India', *Agribusiness*, 36 (3): 363–84.
- Kuwornu J. K. M., Osei E., Osei-Asare Y. B. and Porgo M. (2018) 'Off-farm work and food security status of farming households in Ghana', *Development in Practice*, 28 (6): 724–40.
- Lallukka T., Pitkaniemi J., Rahkonen O., Roos E., Laaksonen M. and Lahelma E. (2010) 'The association of income with fresh fruit and vegetable consumption at different levels of education', *European Journal of Clinical Nutrition*, 64 (3): 324–7.
- Lee M., Lim M. and Kim J. (2019) 'Fruit and vegetable consumption and the metabolic syndrome: a systematic review and dose-response meta-analysis', *British Journal of Nutrition*, 122 (7): 723–33.
- Li Y. C., Jiang B., Zhang M., Huang Z. J., Deng Q., Zhou M. G., Zhao Z. P., Wang Y. F. and Wang L. M. (2017) 'Vegetable and fruit consumption among Chinese adults and associated factors: a nationally representative study of 170,847 adults', *Biomedical and Environmental Sciences*, 30: 863–74.
- Liu M., Tan R. and Zhang B. (2021) 'The costs of "blue sky": environmental regulation, technology upgrading, and labor demand in China', *Journal of Development Economics*, 150: 102610.
- Liu Y., Renwick A. and Fu X. (2019) 'Off-farm income and food expenditure of rural households in China', *British Food Journal*, 121 (5): 1088–100.
- Ma W., Abdulai A. and Ma C. (2018) 'The effects of off-farm work on fertilizer and pesticide expenditures in China', *Review of Development Economics*, 22 (2): 573–91.
- Ma W., Renwick A. and Grafton Q. (2018) 'Farm machinery use, off-farm employment and farm performance in China', *Australian Journal of Agricultural and Resource Economics*, 62 (2): 279–98.
- Ma W. and Wang X. (2020) 'Internet use, sustainable agricultural practices and rural incomes: evidence from China', *Australian Journal of Agricultural and Resource Economics*, 64 (4): 1087–112.
- Ma W., Zheng H., Zhu Y. and Qi J. (2021) 'Effects of cooperative membership on financial performance of banana farmers in China: a heterogeneous analysis', *Annals of Public and Cooperative Economics*, March, apce.12326. <https://doi.org/10.1111/apce.12326>.
- Ma W. and Zhu Z. (2020) 'A note: reducing cropland abandonment in China—do agricultural cooperatives play a role?' *Journal of Agricultural Economics*, 71 (3): 929–35.
- Mathenge M. K., Smale M. and Tschirley D. (2015) 'Off-farm employment and input intensification among smallholder maize farmers in Kenya', *Journal of Agricultural Economics*, 66 (2): 519–36.
- Milajerd A., Ebrahimi-Daryani N., Dieleman L. A., Larijani B. and Esmailzadeh A. (2020) 'Association of dietary fiber, fruit, and vegetable consumption with risk of inflammatory bowel disease: a systematic review and meta-analysis', *Advances in Nutrition*, 6: 1–9.
- Mishra A. K., Mottaleb K. A. and Mohanty S. (2015) 'Impact of off-farm income on food expenditures in rural Bangladesh: an unconditional quantile regression approach', *Agricultural Economics*, 46 (2): 139–48.
- NBS (2020) *China Statistical Yearbook*. Beijing: National Bureau of Statistics of China.
- Owusu V., Abdulai A. and Abdul-Rahman S. (2011) 'Non-farm work and food security among farm households in Northern Ghana', *Food Policy*, 36 (2): 108–18.
- Phillips A., Milte C. M., Opie R. S., Campbell K. J. and Torres S. J. (2020) 'Fruit and vegetable consumption and psychological distress in Australian pregnant and breastfeeding women', *Asia Pacific Journal of Clinical Nutrition*, 29: 348–54.

- Pritchard B., Rammohan A. and Vicol M. (2019) 'The importance of non-farm livelihoods for household food security and dietary diversity in rural Myanmar', *Journal of Rural Studies*, 67: 89–100.
- Qian Y., Nayga R. M., Thomsen M. R. and Rouse H. L. (2016) 'The effect of the fresh fruit and vegetable program on childhood obesity', *Applied Economic Perspectives and Policy*, 38 (2): 260–75.
- Rahman A. and Mishra S. (2020) 'Does non-farm income affect food security? Evidence from India', *Journal of Development Studies*, 56 (6): 1190–209.
- Restrepo B. J., Rabbitt M. P. and Gregory C. A. (2021) 'The effect of unemployment on food spending and adequacy: evidence from coronavirus-induced firm closures', *Applied Economic Perspectives and Policy*, July, 1–20.
- Schmidt E., Mueller V. and Rosenbach G. (2020) 'Rural households in Papua New Guinea afford better diets with income from small businesses', *Food Policy*, 97: 101964.
- Takeshima H., Akramov K., Park A., Ilyasov J., Liu Y. and Ergasheva T. (2020) 'Agriculture–nutrition linkages with heterogeneous, unobserved returns and costs: insights from Tajikistan', *Agricultural Economics*, 51 (4): 553–65.
- Terza J. V., Basu A. and Rathouz P. J. (2008) 'Two-stage residual inclusion estimation: addressing endogeneity in health econometric modeling', *Journal of Health Economics*, 27 (3): 531–43.
- Tesfaye W. and Tirivayi N. (2020) 'Crop diversity, household welfare and consumption smoothing under risk: evidence from rural Uganda', *World Development*, 125: 104686.
- Tian Y., Su L., Wang J., Duan X. and Jiang X. (2018) 'Fruit and vegetable consumption and risk of the metabolic syndrome: a meta-analysis', *Public Health Nutrition*, 21 (4): 756–65.
- Tsiboe F., Zereyesus Y. A. and Osei E. (2016) 'Non-farm work, food poverty, and nutrient availability in northern Ghana', *Journal of Rural Studies*, 47: 97–107.
- Van den Broeck G. and Maertens M. (2017) 'Does off-farm wage employment make women in rural Senegal happy?' *Feminist Economics*, 23 (4): 250–75.
- WHO (2020) *Healthy Diet in China*. World Health Organization.
- WHO-FAO (2004) 'Fruit and vegetable for health: report of a joint FAO/WHO workshop'. In *Handbook of Plant Food Phytochemicals* (Issues 1–3 September). World Health Organization.
- Wolfenden L., Barnes C., Lane C., McCrabb S., Brown H. M., Gerritsen S., Barquera S., Véjar L. S., Munguia A. and Yoong S. L. (2021) 'Consolidating evidence on the effectiveness of interventions promoting fruit and vegetable consumption: an umbrella review', *International Journal of Behavioral Nutrition and Physical Activity*, 18 (1).
- Wong A. Y. S., Chan E. W., Chui C. S. L., Sutcliffe A. G. and Wong I. C. K. (2013) 'The phenomenon of micronutrient deficiency among children in China: a systematic review of the literature', *Public Health Nutrition*, 17 (11): 2605–18.
- Yang G., Kong L., Zhao W., Wan X., Zhai Y., Chen L. C. and Koplan J. P. (2008) 'Emergence of chronic non-communicable diseases in China', *The Lancet*, 372 (9650): 1697–705.
- Ying A., Xu R. and Murphy J. (2019) 'Two-stage residual inclusion for survival data and competing risks—an instrumental variable approach with application to SEER-Medicare linked data', *Statistics in Medicine*, 38 (10): 1775–801.
- Zereyesus Y. A., Embaye W. T., Tsiboe F. and Amanor-Boadu V. (2017) 'Implications of non-farm work to vulnerability to food poverty—recent evidence from northern Ghana', *World Development*, 91: 113–24.
- Zhan J., Liu Y. J., Cai L. B., Xu F. R., Xie T. and He Q. Q. (2017) 'Fruit and vegetable consumption and risk of cardiovascular disease: a meta-analysis of prospective cohort studies', *Critical Reviews in Food Science and Nutrition*, 57 (8): 1650–63.
- Zhang S., Sun Z., Ma W. and Valentimov V. (2020) 'The effect of cooperative membership on agricultural technology adoption in Sichuan, China', *China Economic Review*, 62: 101334.
- Zheng H., Ma W. and Zhou X. (2021) 'Interactive relationship between non-farm employment and mechanization service expenditure in rural China', *China Agricultural Economic Review*. <https://doi.org/10.1108/CAER-10-2020-0251>.
- Zhou X., Ma W., Renwick A. and Li G. (2020) 'Off-farm work decisions of farm couples and land transfer choices in rural China', *Applied Economics*, 52 (57): 6229–47.
- Zhu Z., Ma W. and Leng C. (2020) 'ICT adoption, individual income and psychological health of rural farmers in China', *Applied Research in Quality of Life*. <https://doi.org/10.1007/s11482-020-09879-2>.
- Zhu Z., Ma W., Leng C. and Nie P. (2020) 'The relationship between happiness and consumption expenditure: evidence from rural China', *Applied Research in Quality of Life*. <https://doi.org/10.1007/s11482-020-09836-z>.

Appendix

**Table A1.** Impact of off-farm income ratio and off-farm worker ratio at the household level, and off-farm work intensity of household heads on fruit and vegetable consumption.

	Second stage: Poisson model		Second stage: Tobit model	
	Fruit purchasing frequency	Vegetable purchasing frequency	Fruit consumption expenditure	Vegetable consumption expenditure
<i>Estimation (1)</i>				
Off-farm work intensity	0.010 (0.005)*	0.019 (0.004)***	0.025 (0.019)	0.058 (0.025)**
Control variables	Yes	Yes	Yes	Yes
Observations	558	558	558	558
<i>Estimation (2)</i>				
Off-farm income ratio	0.439 (0.410)	0.759 (0.336)**	2.512 (1.397)*	2.222 (1.856)
Control variables	Yes	Yes	Yes	Yes
Observations	558	558	558	558
<i>Estimation (3)</i>				
Off-farm worker ratio	0.604 (0.655)	0.645 (0.540)	3.711 (2.229)*	2.327 (2.969)
Control variables	Yes	Yes	Yes	Yes
Observations	558	558	558	558

Note: \* < 0.10, \*\* < 0.05, and \*\*\* < 0.01. Standard errors are presented in parentheses. Fruit consumption expenditure and vegetable consumption expenditure are measured at 100 Yuan/month. For the sake of simplicity, we only present the coefficients of the key explanatory variables for Estimations (1)–(3).



**Table A2.** Impacts of fruit and vegetable growing status on their consumption.

Variables	Poisson model		Tobit model	
	Fruit purchasing frequency	Vegetable purchasing frequency	Fruit consumption expenditure	Vegetable consumption expenditure
Fruit growing status	−0.229 (0.070) <sup>***</sup>		−0.157 (0.212)	
Vegetable growing status		−0.408 (0.032) <sup>***</sup>		−0.532 (0.166) <sup>***</sup>
Age	−0.015 (0.002) <sup>***</sup>	−0.024 (0.002) <sup>***</sup>	−0.035 (0.007) <sup>***</sup>	−0.029 (0.010) <sup>***</sup>
Gender	−0.088 (0.043) <sup>**</sup>	0.381 (0.037) <sup>***</sup>	−0.003 (0.138)	0.159 (0.183)
Education	0.020 (0.006) <sup>***</sup>	−0.010 (0.005) <sup>**</sup>	0.002 (0.018)	0.011 (0.024)
Household size	0.058 (0.010) <sup>***</sup>	0.055 (0.008) <sup>***</sup>	0.109 (0.034) <sup>***</sup>	0.078 (0.045) <sup>*</sup>
Farm size	0.001 (0.002)	−0.004 (0.002) <sup>*</sup>	0.000 (0.006)	0.007 (0.008)
Elder member ratio	−0.400 (0.096) <sup>***</sup>	−0.066 (0.074)	0.026 (0.265)	−0.004 (0.347)
Child member ratio	0.558 (0.136) <sup>***</sup>	0.167 (0.113)	0.959 (0.461) <sup>**</sup>	1.033 (0.608) <sup>*</sup>
Asset ownership	0.052 (0.050)	−0.009 (0.040)	0.029 (0.158)	−0.470 (0.204) <sup>**</sup>
Shandong	0.337 (0.050) <sup>***</sup>	0.387 (0.041) <sup>***</sup>	0.400 (0.151) <sup>***</sup>	0.332 (0.200) <sup>*</sup>
Henan	−0.146 (0.062) <sup>**</sup>	−0.172 (0.053) <sup>***</sup>	−0.227 (0.178)	−0.335 (0.236)
Constant	1.844 (0.132) <sup>***</sup>	2.870 (0.110) <sup>***</sup>	1.879 (0.436) <sup>***</sup>	2.380 (0.580) <sup>***</sup>
Observations	558	558	558	558

Note: \* < 0.10, \*\* < 0.05, and \*\*\* < 0.01. The reference province is Anhui. Standard errors are presented in parentheses. Fruit consumption expenditure and vegetable consumption expenditure are measured at 100 Yuan/month.